



Stabilization of lateritic soil with cement kiln dust for road pavement material based on defined curing temperature conditions

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General Note

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ABSTRACT

The influence of curing temperature on the strength development of cement-stabilized clay has been widely reported in literature. However, there are fewer studies focusing on cement kiln dust-stabilized lateritic soil. Three different samples was compacted at -2, 0, +2 and +4 % of Optimum Moisture Content (OMC) at British Standard heavy compaction energy was cured for a period of 7, 14 and 28, at a constant temperature of 0, 25 \pm 2 and 45 °C. The variation observed, indicated that treated specimen at 0% of optimum moisture content (normal OMC) develop higher Unconfined Compressive Strength (UCS) value than mixture at -2, +2, +4 optimum moisture content (OMC) and especially at 0°C and 25°C temperature. However, at 45°C curing temperature the +4% of OMC recorded the maximum UCS value. The UCS values generally increased with increase in Cement Kiln Dust (CKD) content to a peak value at 5 % CKD before reducing which can be largely attributed to the pozzolanic input of CKD. The observable trend shows that the UCS value increases as the molding water increase from dry to wet of optimum and also increases as the temperature of curing increases. UCS values recorded from samples compacted at OMC at a temperature of 45°C met the requirement of 687–1373 kN/m² for sub-base as specified by Ingles and Metcalf.

Keywords: Compaction, Curing temperature, Unconfined compressive strength UCS, Optimum moisture content OMC, Molding water content.

1. INTRODUCTION

The traditional design approach for assessing the suitability of road pavement material involves utilizing the optimum moisture content at maximum dry density to arrive at the best water content to use for stabilizing agents. In geotechnical engineering any process which improves the engineering properties of deficient soils is referred to as stabilization (Yoder and Witczack, 1975; Gilliot, 1987). Primarily, the objectives of soil stabilization are to improve the soil strength, decrease permeability and water absorption, improve soil bearing capacity and the durability under adverse weather condition.

However, the behavior of untreated specimen and treated specimen has been shown to be different. This is so because untreated specimen develops maximum shear strengths at maximum dry densities which occur at optimum moisture content. But for treated specimens, Researchers such as Moses and Afolayan, 2013, Osinubi *et al.*, 2014, have observed that for every pozzolana there is molding water content required for achieving maximum shear strength which is completely independent of the maximum dry density and optimum moisture content. And this value could be on the dry or wet side of optimum moisture content depending on the compactive energy level and the type of pozzolana.

The temperature of curing is another key important factor that has not been put into consideration as it affects strength development. This can be expected especially under temperate and hot desert temperature condition where hydration of pozzolanas can either be increased or decreased due to the prevailing weather condition. Some of the researchers who have worked on the effect of temperature such as George *et al.*, (1992), Huisheng *et al.*, (2002) have worked on response of shear strength parameters of some lateritic soils to pre-test temperature, the effect of temperature on lime hydration and the effect of curing temperature on strength characteristics and hydration reaction of steel slag hydrated matrix.

Laterites are widely distributed throughout the world in the regions with high rainfall, but especially in the inter-tropical region. Lateritic soils have been extensively used in the last decades in dam and road construction. The term Laterite is derived from the Latin word —later, meaning brick. It was first used in 1807 by Buchanan to describe a red iron-rich material found in the southern parts of India.

Cement kiln dust (CKD) is an industrial waste from cement production. As with most large manufacturing industries, by-products are generated. Cement kiln dust is a fine grained solid material generated as the primary inherent process residue at all cement plants. In 1990, it was reported that an average 9 tons of Cement kiln dust was produced for every 100 tons of clinker in the U.S.A (Corish and Coleman, 1995). The quantities and characteristics of CKD generated depend upon a number of operational factors and characteristics of the inputs to the manufacturing process. Therefore, this research work intends to investigate the effect of molding water content on the strength development of CKD treated lateritic soil specimens and to ascertain the influence of temperature on their strength development.

2.0 MATERIALS AND METHODS

2.1 Materials

2.1.1 Soil: The lateritic soil used in this study is to be obtained from a burrow pit by method of disturbed sampling at Km 15 along the Zaria—Sokoto road in Zaria (latitude 11°15' and longitude 7°45'E), Kaduna State Nigeria. The soil is classified as CL according to the unified soil classification system. X-ray diffraction (XRD) and differential thermal analysis (DTA) of soil from the study borrow area reported by Osinubi (1998a, b) show that the clay mineralogy is predominantly kaolinite.

2.1.2 Cement Kiln Dust: The cement kiln dust to be used is to be obtained from freshly deposited heaps of the waste at the Sokoto cement production plant located in Nafada Local Government Area of Sokoto state, (Latitude 0° 19'N and Longitude 11° 30'E), Nigeria. The CKD is to be sieved through BS sieve No. 200 and was stored in air-tight containers before usage. Chemical analysis of CKD is to be carried out at Chemical analysis of the CKD specimen is to be carried out at the National Geological Survey Laboratory Kaduna, Nigeria.

2.2 Methods

2.2.1 Index Properties: Laboratory tests is to be conducted to determine the index properties of the natural soil and soil – cement kiln dust mixtures in accordance with British Standards BS 1377 (1990) and BS 1924 (1990) respectively.

2.2.2 Compaction: The compactive energy level to be used is British standard heavy (BSH). The laboratory test involving: moisture – density relationship unconfined compressive strength (UCS). Air dried soil samples passing through BS sieve with 4.76mm aperture mixed with 0, 2.5, 5.0, 7.5 and 10.0 % cement kiln dust by weight of dry soil were used. The BSH compaction moisture density relationships is to be determined using energy derived from a hammer of 4.5kg mass falling through a height of 45cm in a 1000cm³ mould. The soil is to be compacted in 5 layers, each receiving 27 blows.

2.2.3 Unconfined Compressive Strength: The test is to be carried out in accordance with British Standards (BS 1990). Unconfined compressive strength (UCS) test is to be performed on cylindrical specimens 38.1mm in diameter and 76.2mm length. This ensured testing of soil specimens with length to diameter ratio of 2:1. Air dried soil – CKD mixtures are to be compacted at – 2%, 0%, +2% and +4% of the optimum moisture content (OMC) and maximum dry density of the BSH energy levels. After each compaction, the soil is to be extruded from the mould and sealed in polythene bag to minimize moisture loss, cured for a period of 7, 14 and 28, at a constant temperature of 0, 25 ± 2 and 45 °C. After curing specimens will be placed in a load frame machine driven strain controlled at 0.10%/min until failure occurred.

(UCS) value can be estimated using the following equations:

$$UCS = ((RCr)(1 - (L_1 / L_o))) / 100 A_o$$

where A_o = the initial area of cross-section (mm²), $\epsilon\%$ = x/L_o , $\epsilon\%$ = axial strain percent, L_o = initial length of specimen, D = initial diameter of specimen (mm), Cr N/division = mean calibration of load ring, R divisions = load ring reading at strain, ϵ ; A (mm²) = area of cross-section at strain, ϵ ; $R \times Cr$ Newton's = load on specimen at strain, ϵ ; σ = compressive stress at strain, ϵ . The ring calibration CR can be assumed to be constant

3. RESULTS AND DISCUSSION

Index properties

The index properties and compactions of the natural and treated lateritic soil are shown in Table 4. The soil is classified as A-7-6 (7) according to AASHTO classification system (AASHTO, 1986) and CL according to the Unified Soil Classification System (ASTM, 1992).

Table 3 Physical Properties of Natural and Treated Lateritic Soil

Property	Cement Kiln Dust, %				
	0	2.5	5.0	7.5	10.0
Natural moisture content (%)	21.6	-	-	-	-
Liquid Limit, %	42.6	43.5	44.5	44.2	44.0
Plastic Limit, %	24.3	25.0	25.0	26.1	27.3
Plasticity Index, %	18.3	18.5	19.5	18.1	16.7
Linear Shrinkage, %	12.1	12.1	12.9	13.6	13.6
Percentage Passing BS No. 200 Sieve.	54.6	56.7	64.6	65.8	59.2
AASHTO Classification	A-7-6(7)	A-7-6(8)	A-7-6(11)	A-7-6(11)	A-7-6(8)
USCS Classification	CL	CL	CL	CL	CL
Specific Gravity	2.71	2.66	2.64	2.60	2.61
MDD, Mg/m ³	1.71	1.68	1.67	1.66	1.66
OMC, %	17.5	18.5	19.0	19.0	19.5
pH Value	6.7				
Color	Reddish Brown				
Dominant clay mineral	Kaolinite				

The Influence of Curing Period and Different Temperature on The Compressive Strength of Cement Kiln Dust Treated Lateritic Soil.

The result shown in Fig.1-12 demonstrates the effect of CKD addition at progressive elevated curing temperature on compressive strength of CKD treated lateritic soil. The observed trend for 0°C, 25°C and 45°C cured specimen at -2, 0, +2 and +4% of the optimum moisture content, show an increase in the compressive strength at higher temperature. This is to be expected as chemical reactions naturally increase with increasing temperature, this is consistent with the work of researchers such as Wang *et al.*, (1986), Huisheng *et al.*, (2002) and Harichane *et al.*, (2011).

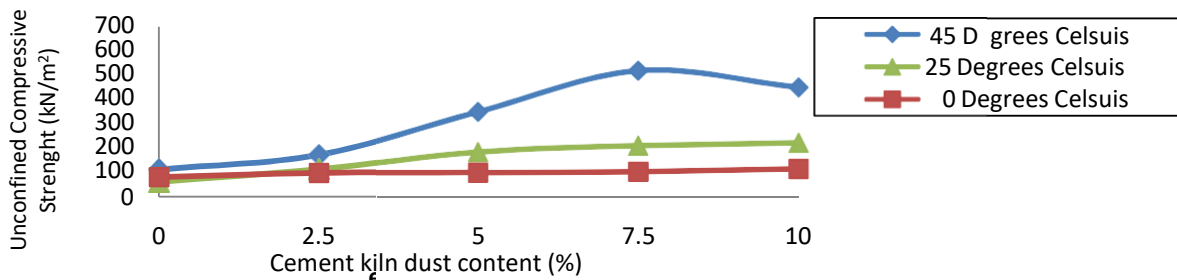


Fig. 1: Variiation of 7 Days Cur d Specimen at Different Temperature and Cement Kiln Dust Content for -2% of the Optimum Moisture Content

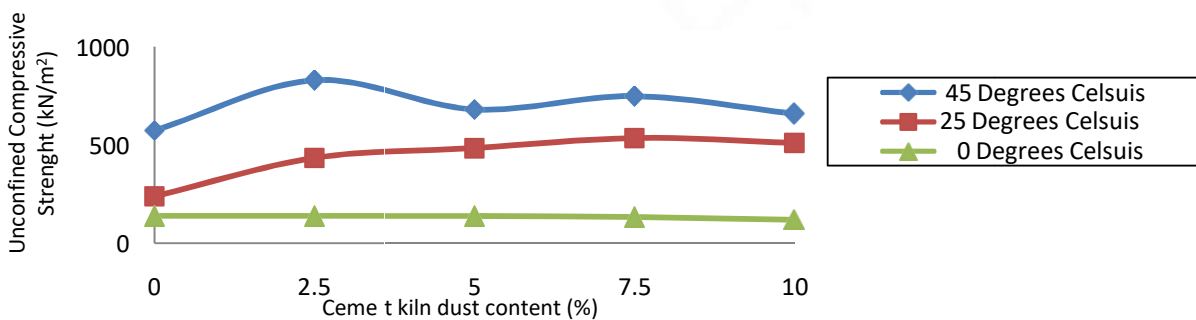


Fig. 2: Variiation of 7 Days Cured Specimen at Different Temperature and Cement Kiln Dust Content for 0% of the Optimum Moisture Content

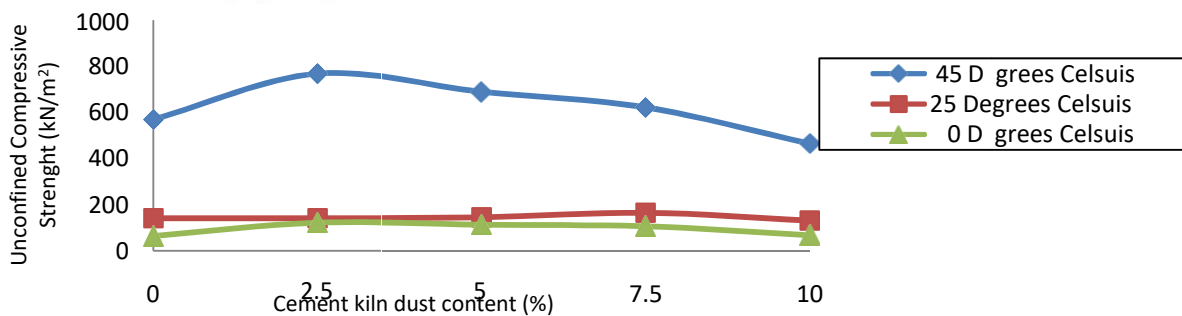


Fig. 3: Variiation of 7 Days Cured Specimen at Different Temperature and Cement Kiln Dust Content for +2% of the Optimum Moisture Content

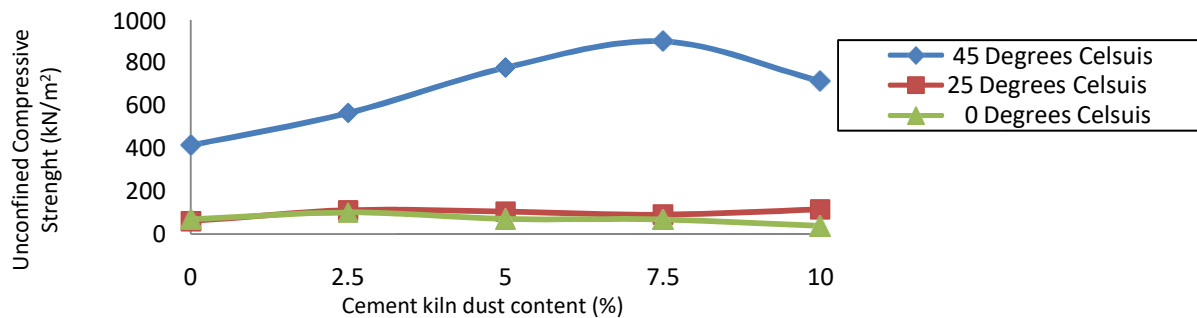


Fig. 4: Variation of 7 Days Cured Specimen at Different Temperature and Cement Kiln Dust Content for +4% of the Optimum Moisture Content

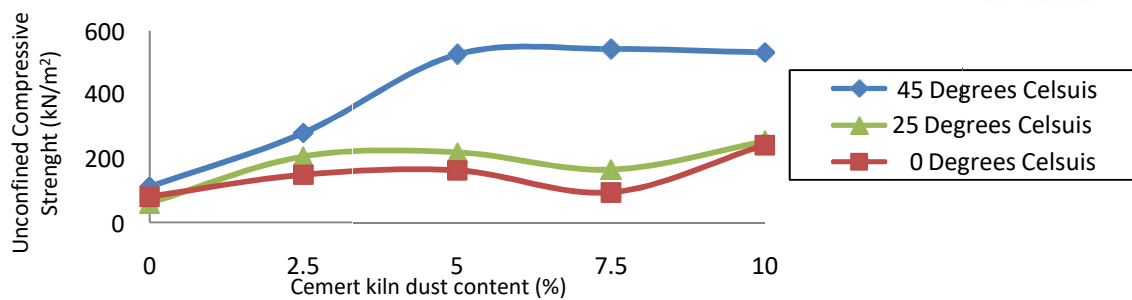


Fig. 5: Variation of 14 Days Cured Specimen at Different Temperature and Cement Kiln Dust Content for -2% of the Optimum Moisture Content

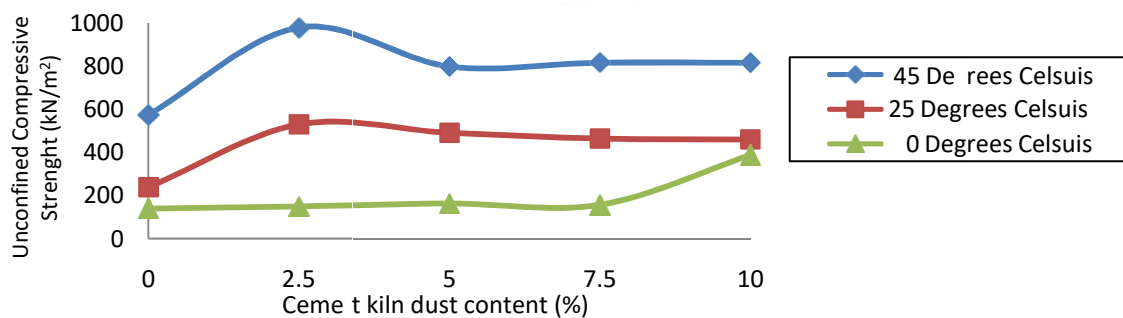


Fig. 6: Variation of 14 Days Cured Specimen at Different Temperature and Cement Kiln Dust Content for 0% of the Optimum Moisture Content

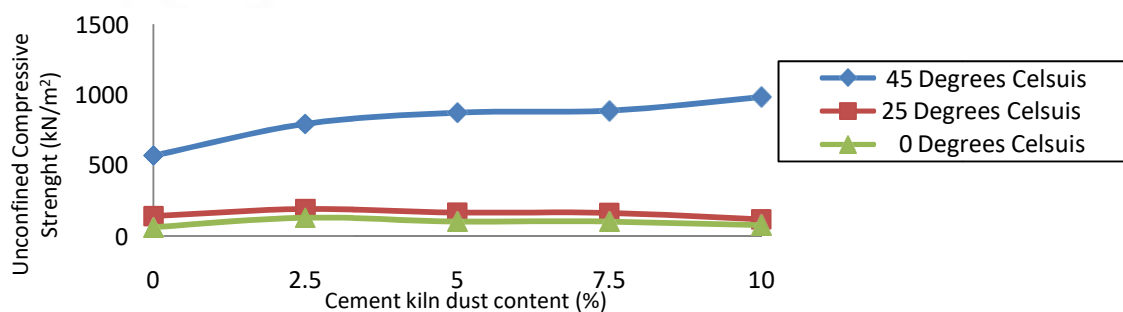


Fig. 7: Variation of 14 Days Cured Specimen at Different Temperature and Cement Kiln Dust Content for +2% of the Optimum Moisture Content

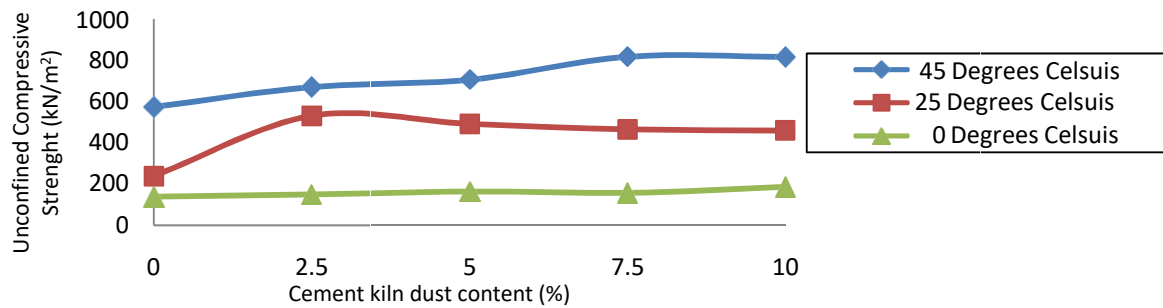


Fig. 8:Variation of 14 Days Cured Specimen at Different Temperature and Cement Kiln Dust Content for +4% of the Optimum Moisture Content

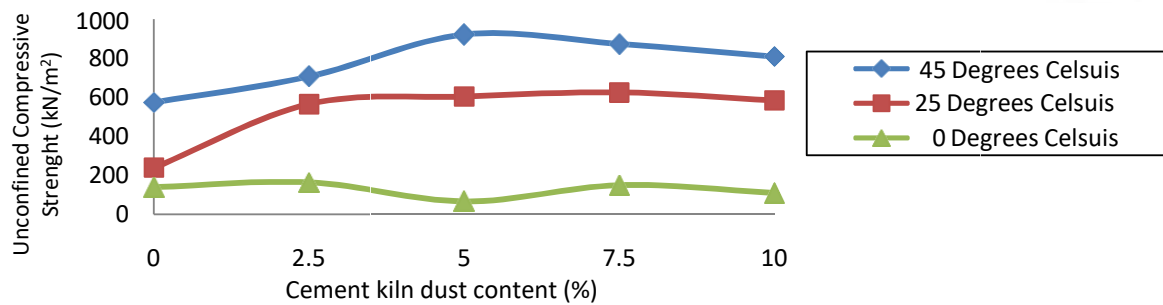


Fig9:Variation of 28 Days Cured Specimen at Different Temperature and Cement Kiln Dust Content for -2% of the Optimum Moisture Content

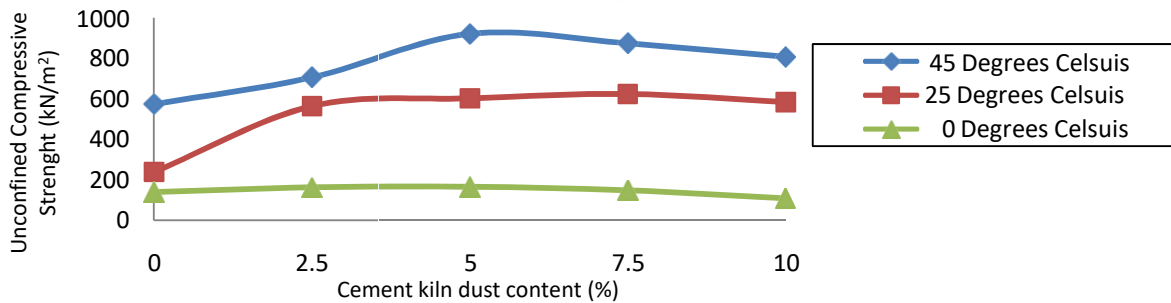


Fig. 10: Variation of 28 Days Cured Specimen at Different Temperature and Cement Kiln Dust Content for 0% of the Optimum Moisture Content

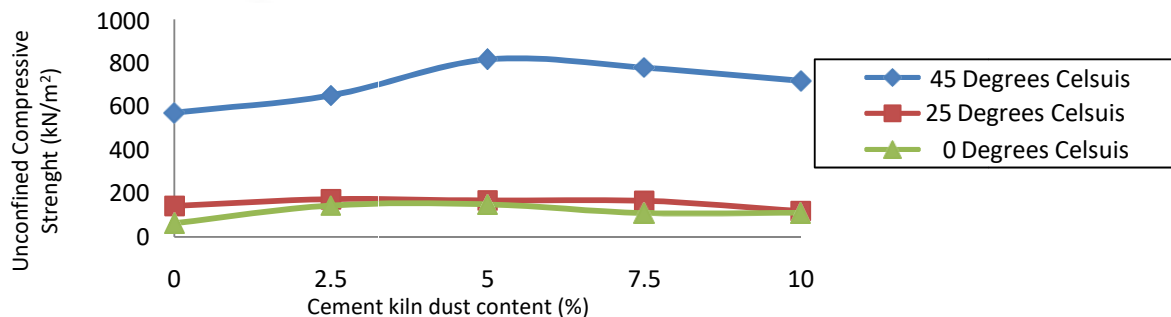


Fig. 11: Variation of 28 Days Cured Specimen at Different Temperature and Cement Kiln Dust Content for +2% of the Optimum Moisture Content

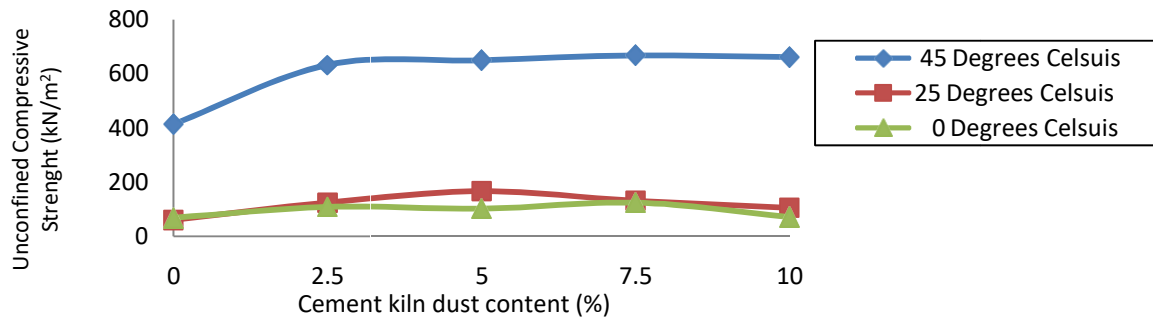


Fig. 12: Variation of 28 Days Cured Specimen at Different Temperature and Cement Kiln Dust Content for +4% of the Optimum Moisture Content

The Influence of Molding Water Content at Constant Temperature on the Compressive Strength of Cement Kiln Dust Treated Lateritic Soil.

The result in Fig.13-21 shows a variation of 7, 14 and 28 days cured specimen at -2, 0, +2, and +4 optimum moisture content and cement kiln dust content for 0°C, 25°C and 45°C temperature. The variation observed, indicated that treated specimen at 0% of optimum moisture content (normal OMC) develop higher UCS value than mixture at -2, +2, +4 optimum moisture content (OMC) especially at 0°C and 25°C. This finding is in agreement with the research work done by Moses and Afolayan, 2013 and Osinubi *et al.*, 2015. They reported that there is a marked deviation on the dry side of optimum which normally records higher UCS value for natural soil especially for compactions at the BSH energy level. This trend could be as a result of the molding water contents being insufficient to meet the hydration demand on the dry side of optimum. While on the other hand at 0% OMC full hydration capacity has been achieved and with higher molding water content excessive water inhibit full strength development. However, 45°C curing temperature +4% of OMC produced the maximum UCS value. This may as a result of moisture loss in the cause of curing the specimen at high temperature, thus reducing the excess moisture present in the mixture, consequently enhancing optimal hydration process of specimen.

The UCS values generally increased with increase in CKD content which can be largely attributed to the pozzolanic input of CKD. Kamon and Nontananandh (1991), Moses and Saminu (2012) and Moses and Afolayan (2013), Osinubi *et al.*, (2015) have suggested that in order for reactions to take place, the hydration modulus must be greater than 1.7. The hydraulic modulus of the CKD specimen used in this study adequately satisfies this criterion. The mixture of laterite and lime from cement kiln dust under an alkaline condition provides a conducive environment for the dissolution of silicates and aluminates in the soil, which react with Ca^{+2} cations to form cementitious compounds, through the hydration process. The hydration products formed are the tricalcium silicate, dicalcium silicates, tricalcium aluminates and tetracalcium aluminate hydrates. The tricalcium silicates are responsible for the early gain in strength, while the dicalcium silicates are responsible for the later gain in strength which is a slow process called pozzolanic reaction (Stephen 2006).

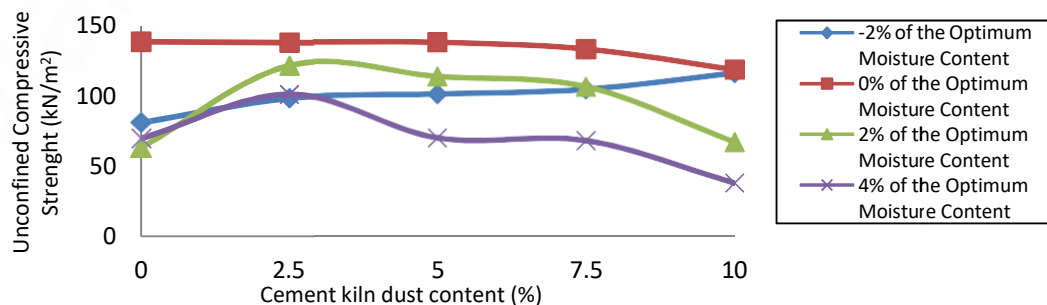


Fig. 13: Variation of 7 Days Cured Specimen at Different Optimum Moisture Content and Cement Kiln Dust Content for 0 Degree Celsius Temperature

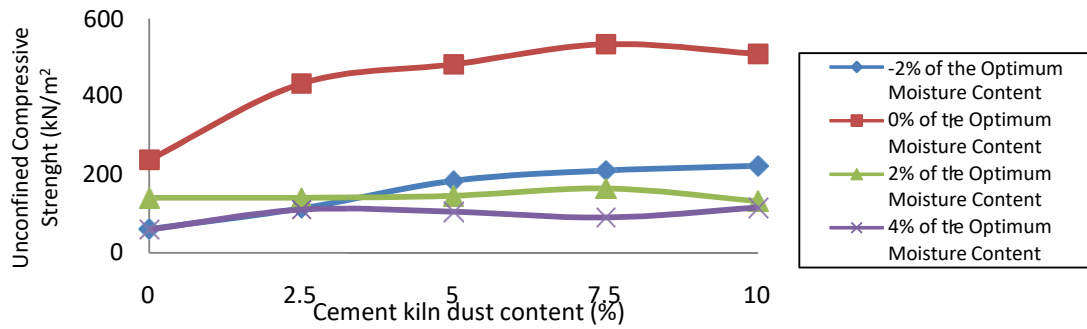


Fig. 14: Variation of 7 Days Cured Specimen at Different Optimum Moisture Content and Cement Kiln Dust Content for 25 Degree Celsius Temperature

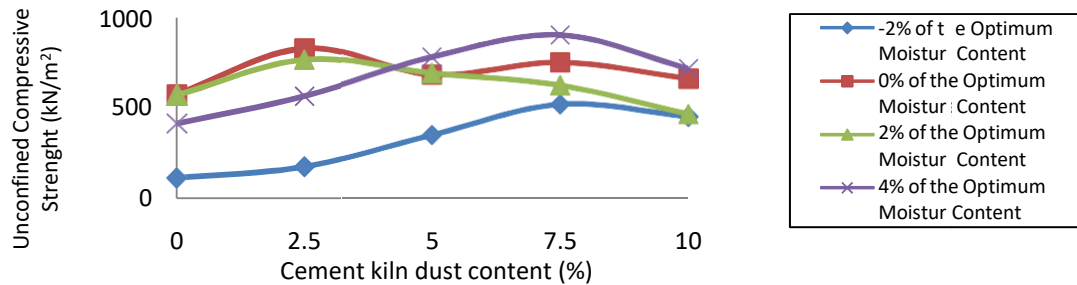


Fig. 15: Variation of 7 Days Cured Specimen at Different Optimum Moisture Content and Cement Kiln Dust Content for 45 Degree Celsius Temperature

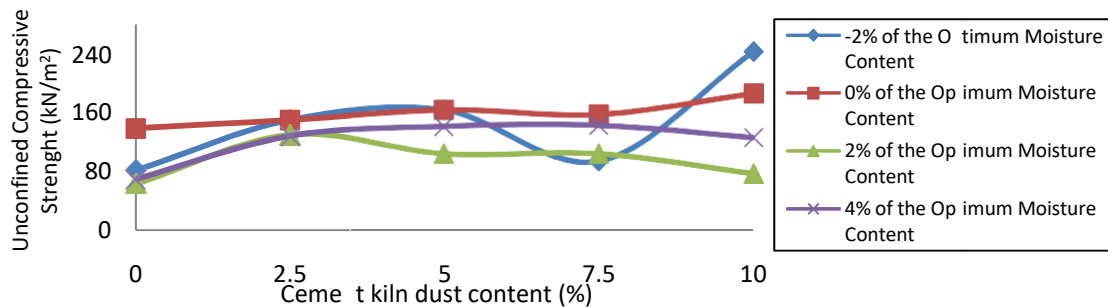


Fig. 16: Variation of 14 Days Cured Specimen at Different Optimum Moisture Content and Cement Kiln Dust Content for 0 Degree Celsius Temperature

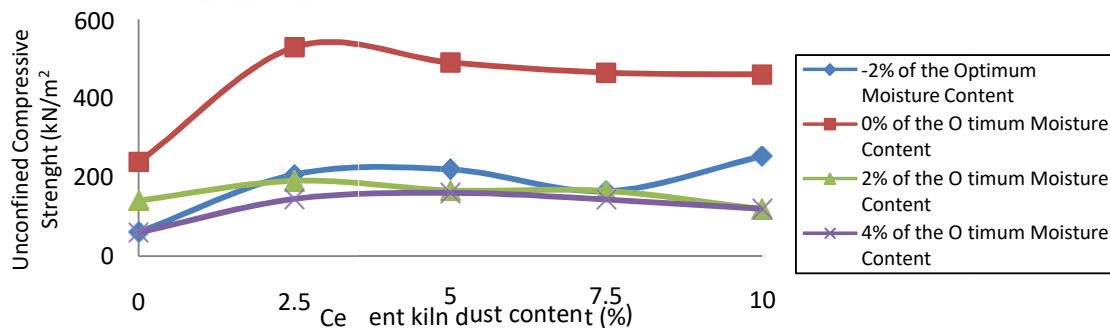


Fig. 17: Variation of 14 Days Cured Specimen at Different Optimum Moisture Content and Cement Kiln Dust Content for 25 Degree Celsius Temperature

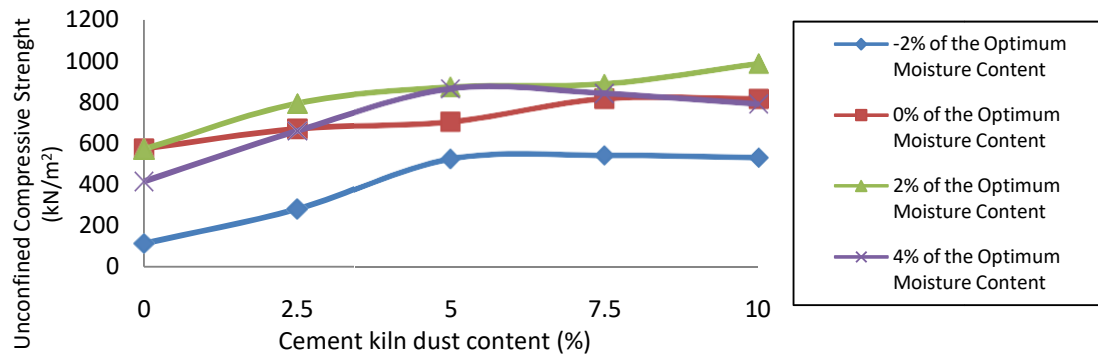


Fig. 18: Variation of 14 Days Cured Specimen at Different Optimum Moisture Content and Cement Kiln Dust Content for 45 Degree Celsius Temperature

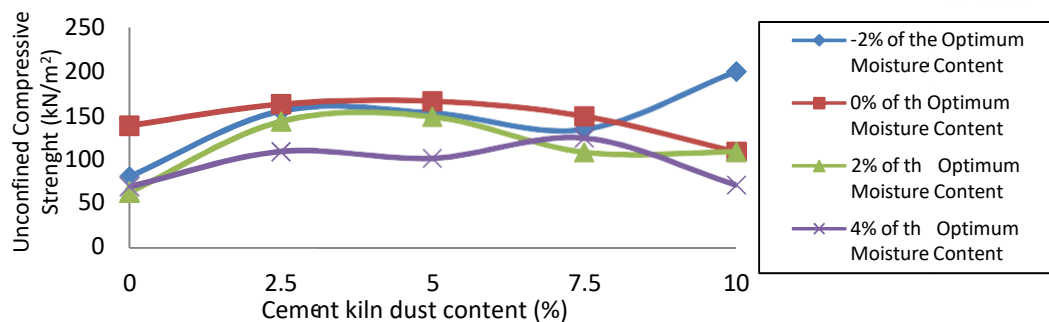


Fig. 19: Variation of 28 Days Cured Specimen at Different Optimum Moisture Content and Cement Kiln Dust Content for 0 Degree Celsius Temperature

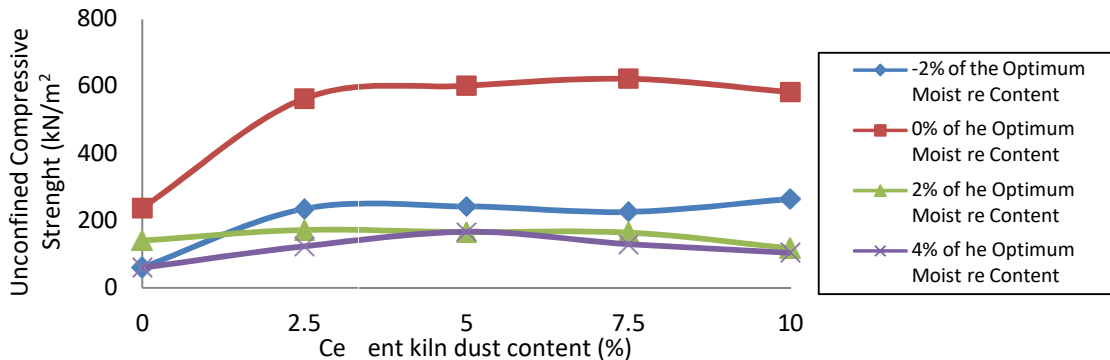


Fig. 20: Variation of 28 Days Cured Specimen at Different Optimum Moisture Content and Cement Kiln Dust Content for 25 Degree Celsius Temperature

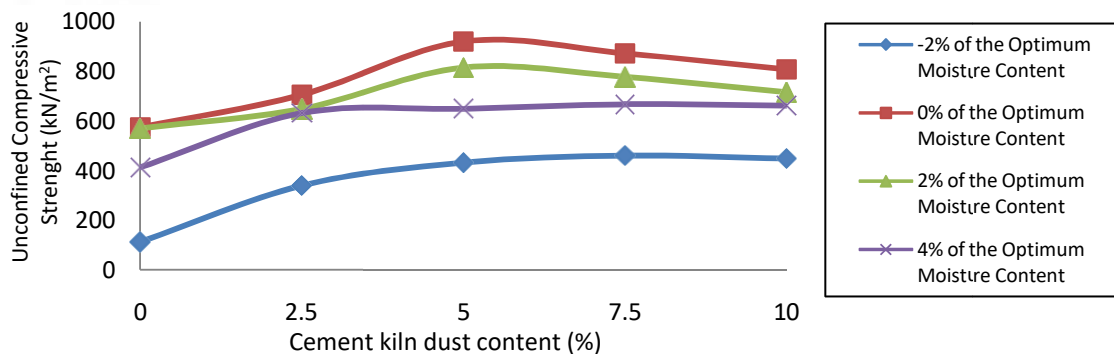


Fig. 21: Variation of 28 Days Cured Specimen at Different Optimum Moisture Content and Cement Kiln Dust Content for 45 Degree Celsius Temperature

The Influence of Curing Period at Constant Molding Moisture Content and Constant Temperature on the Compressive Strength of Cement Kiln Dust Treated Lateritic Soil.

Fig. 22-25 shows the variation of compressive strength with cement kiln dust content for cured days at 0 degree, 25 degree, and 45 degree temperature and -2%, +2, +4 and 0% of the optimum moisture content. The result indicates an increase in the compressive strength as age of curing increases, in line with other research work (Osinubi and Stephen, 2007; Osinubi and Moses, 2011; Moses and Afolayan, 2013 and Osinubi *et al.*, 2015).

The gain in strength of specimens with age was due primarily to the long-term hydration reaction that resulted in the formation of cementitious compounds. The increase in UCS values could be attributed to ion exchange at the surface of clay particles (Osinubi and Stephen, 2007; Osinubi and Moses, 2011)

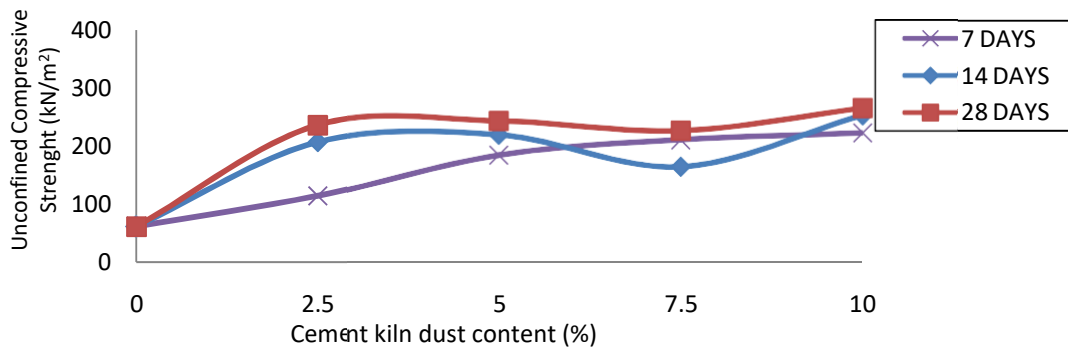


Fig.22 variation of compressive strength wit cement kiln dust content for cured days at 25 degree temperature and -2% of the optimum moisture content

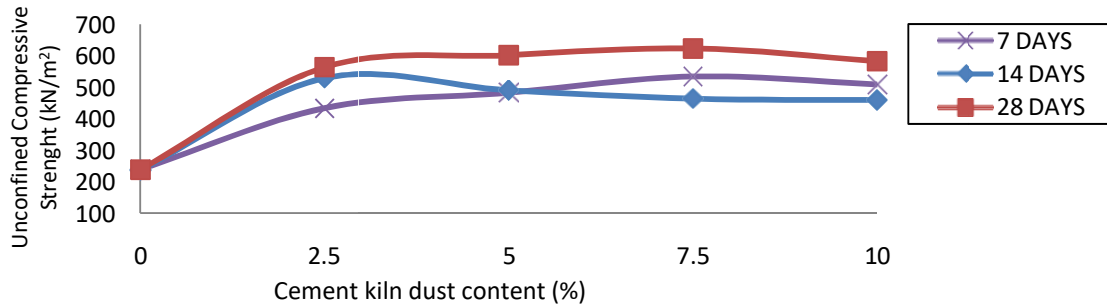


Fig.23 variation of co pressive strength wit cement kiln dust content for cur d days at 25 degree temperature and 0% of the optimum moisture content

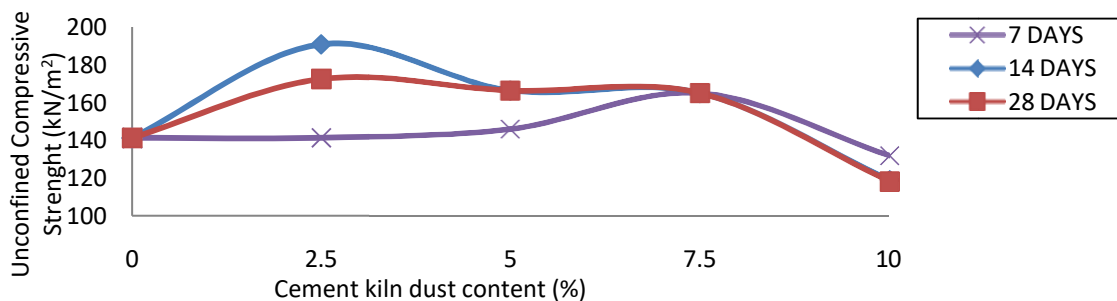


Fig.24 variation of compressive strength wit cement kiln dust content for cured days at 25 degree temperature and +2% of the optimum moisture content

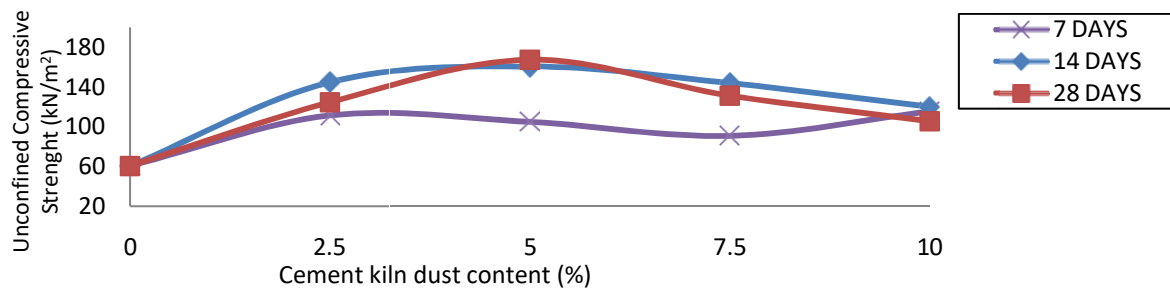


Fig.25 variation of compressive strength wit cement kiln dust content for cured days at 25 degree temperature and +4% of the optimum moisture content

4. CONCUSION

Based on the results obtained from the investigation carried out, the lateritic soil used is an A-7-6 (7) or CL soil in AASHTO (1986) and USCS (ASTM, 1992) Classification Systems, respectively. The liquid limit, plastic limit and plasticity index of the natural soil are 42.6, 24.3 and 18.3 % respectively. The UCS value obtained increases as the curing period increase from 7, 14 and 28 days and also increases as the curing temperature increases from 0°C, 25°C and 45°C respectively. The observed trend for 0°C, 25°C and 45°C cured specimen at -2, 0, +2 and +4% of the optimum moisture content, show an increase in the compressive strength at higher temperature. The variation observed, indicated that treated specimen at 0% of optimum moisture content (normal OMC) develop higher UCS value than mixture at -2, +2, +4 optimum moisture content (OMC) especially at 0°C and 25°C. The observable trend shows that the UCS value increases as the molding water increase from dry to wet of optimum and also increases as the temperature of curing increases. UCS values recorded from samples compacted at OMC at a temperature of 45°C met the requirement of 687–1373 kN/m² for sub-base as specified by Ingles and Metcalf (1972) but it is less than the 1720 kN/m² recommended by TRRL (1977) as criterion for adequate cement stabilization.

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